BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Operational Constraints and Requirements Associated with a 44-Hour Turnaround Capability for the Apollo/Saturn V - Case 320

DATE: June 28, 1968

FROM: G. W. Craft
D. M. Duty
C. H. Eley III
G. J. McPherson Jr.

ABSTRACT

In reply to a recent action item from the Lunar Site Selection Board, KSC has reassessed the Apollo/Saturn V scrub-turnaround operations to identify what redesign or mission considerations would be required to achieve a 44-hour capability.

The problem in reducing the time required to turn-around (or recycle) from the current three day capability to two days is primarily associated with replenishing CSM/LM cryogenics. Under the present system design, some significant reductions could be made if the CSM and LM cryogen servicing operations were performed in parallel. However, parallel servicing is contrary to present KSC safety policy since pad personnel would be exposed to a higher level of hazard during the operations. An alternative would be to move the CSM and LM cryogen servicing from the MSS, where it is presently performed, to the LUT. Unfortunately, the requisite redesign involved would be expensive and time consuming to implement.

It is recognized that as the program progresses and experience is gained, many efficiencies may be introduced which will reduce the time required to recycle the vehicle. However, it appears that a <u>realistic</u> 44-hour capability will not be possible under the present system design if reservicing space-craft consumables is required.

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MEMORANDUM FOR FILE

1. INTRODUCTION

The time required to recycle an Apollo/Saturn V following a scrub in order to attempt a launch in a second window has been of considerable importance in formulating lunar mission planning. Launch Operations at KSC has recently assessed their capability in this regard, and based on study and previous experience has determined that approximately three days (∿64 hours) will be required if a scrub occurs after the launch vehicle cryogenics are loaded.

An action item generated at a recent meeting of the Lunar Site Selection Board (Reference 1) requested that KSC reassess their scrub-turnaround capability and identify what redesign or mission considerations would be required to achieve a 44-hour (2 day) recycle capability. The interim response from KSC is attached as Appendix I. The reply indicates briefly that the lifetimes of the LM Supercritical Helium (SHe) and Service Module fuel cell consumables directly impacts our ability to shorten the vehicle turnaround time to any great degree. The authors who also participated in the KSC study effort are presenting in this paper some background information based partly on work done by KSC and partly on an independent look at the operational constraints and requirements associated with a 44-hour turnaround capability.

2. REQUISITES FOR A 44-HOUR TURNAROUND CAPABILITY

Appendix I indicates the following conditions are required to reduce the SV turnaround capability to 44 hours or less:

a. Move the CSM and LM cryogenic servicing capability from the MSS to the Mobile Launcher or extend the usable lifetimes.

b. Simplification of spacecraft cryogenic servicing systems.

c. Implement a capability to service SM and LM cryogenics in parallel, assuming the safety considerations are acceptable.

d. Reduce or eliminate entry into the launch vehicle to preclude disconnect/reconnect of Dispersion System S&A blocks and the resultant serial work effort involving the MSS platforms.

e. Improve access to the SLA/IU area and a reduction in the tasks to be performed in this congested area.

3. <u>COMMENTS</u>

A scrub-turnaround operation is basically performed in three separate phases.

a. Backout Phase - operations performed which safe the vehicle and establish access (remove crew, detank LV, return MSS, etc.)

b. Reservice/Reverification Phase - reservicing and re-testing operations to prepare the vehicle for the launch countdown (replenish CSM/LM consumables, P.U. calibrations, etc.)

c. Launch Countdown Phase - essentially a repeat of the initial launch countdown (remove MSS, load LV cryos, crew ingress, etc.)

The problem in achieving <u>significant</u> reductions in the scrub-turnaround (or recycle) time for the Apollo/Saturn V is mainly associated with reducing the time required to complete the second phase, (b) above. As shown in the figure attached to Appendix I, reservicing the CSM/LM cryogenics comprises the critical path of operations in this phase.

It should be stated at the outset that under the present system design, and with some changes to basic safety policy, the present turnaround capability <u>could</u> be reduced to a point considerably closer to the desired 44-hours. Figure 1 is a conjectural 44-hour turnaround flow which was developed at KSC to show a possible way of achieving the objective. Unfortunately, this flow involves parallel servicing operations with the LM and CSM cryogenics, something which would expose pad personnel to a higher level of hazard during the time these tasks were being accomplished. Such parallel servicing is also contrary to present KSC safety policy. In addition, some of the time-lines in Figure 1 have not been demonstrated. The figure has been included, however, for reference purposes and also to show that KSC is actively pursuing various methods of achieving a 44-hour turnaround capability.

From the above discussion, the reasons become clearer as to why the majority of required conditions listed in Section 2 are concerned with CSM/LM cryogen reservicing. For additional background information, a description of the operations and constraints associated with 2(a), 2(b) and 2(c) is presented in Appendixes III and IV. An analysis of the operations and constraints associated with 2(d) and 2(e) is contained in Appendix II. A description of the APS Bladder Bleed Requirement is included in Appendix V as background information on the question of "those items which would impact a second scrub-turnaround."

It is felt that solutions for several of the conditions listed in Appendix I may be readily available. Other suggested solutions, however, may be most difficult to achieve. For instance, Appendixes III and IV show that requisite redesign to move the CSM and LM cryogenic servicing capability from the MSS to the Mobile Launcher would prove both expensive and time consuming to implement--something which is of questionable feasibility at this point in the Apollo program. (However, some of the alternatives to such redesign are also discussed in those Appendixes.)*

It is recognized that as the program progresses and experience is gained, many efficiencies may be introduced which could reduce the present turnaround figure. This does not suggest that improvements by redesign should be abandoned, however, but rather those which engineering analysis indicate can be most productively applied should be adopted. Certainly compromises with safety could also be accepted, but only after a full understanding of the risks involved.

G. W. Craft

D. M. Duty

C. H. Eley III

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GWC
DMD
2032-CHE-gmp
GJM

Attachments
Appendixes I-V
Figures 1-5

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*Also Discussed in References 2, 3, 4 and 6.

References

1. Memorandum from MA/Apollo Program Director dated May 6, 1968, "Minutes of the Apollo Site Selection Board Meeting of March 26, 1968."

2. "Analysis of Operations and Constraints Associated with the Mobile Service Structure (MSS) at Launch Complex 39," by G. J. McPherson Jr., 8 May 1968, Case 320, Bellcomm TM-68-2032-1.

3. Bellcomm Memorandum, "A Proposal for Uprating the LM Supercritical Helium (SHe) System - Case 320," dated March 29, 1968, by D. M. Duty.

4. MSC Memorandum, "Loading of Supercritical Helium," by A. D. Mardel, dated 9 February 1968. Reference PT7-0/68-184.

5. "Supercritical Cryogenics Management Between MSS Removal and Launch - Apollo 6 - Case 320," Bellcomm Memorandum dated March 19, 1968, by G. W. Craft.

6. Bellcomm Memorandum (Draft): "Parallel Operations as a means of Reducing the Time required for Launch Vehicle Cryogenics Loading." Case 320, by G. W. Craft.

APPENDIX I

JOHN F. KENNEDY SPACE CENTER, NASA
KENNEDY SPACE CENTER, FLORIDA 32899

MAY 21 [illegible]

IN REPLY REFER TO AP-OPN-2

TO : Manned Spacecraft Center
Attention: Manager, Apollo Spacecraft Program, PA

FROM : Apollo Program Manager

SUBJECT : Lunar Site Selection Board Action Items

REFERENCE: (a) Memorandum from MA/Apollo Program Director to Distribution, dated May 6, 1968, Subject: Minutes of the Apollo Site Selection Board Meeting of March 26, 1968

Attached is a copy of the report from the Manager, Test Planning Office LO-OPN, in answer to action items six and seven of the March 26, 1968, Lunar Site Selection Board Meeting (See Reference (a).

As you will note, the studies of the lifetime of SH_e and fuel cell consumables directly impact our ability to shorten the turn-around times. We hope to be able to complete these studies by June 15, 1968.

R. O. Middleton

R. O. Middleton
Rear Admiral, U. S. Navy

Enclosure: (1) Lunar Site Selection Board Action Items

cc:
Apollo Program Director, MA
Manager, Saturn V Program Office, I-V-MGR

See distribution

Manager, Test Planning Office, LO-P

Lunar Site Selection Board Action Items

1. At the March 28, 1968 Lunar Site Selection Bo
a status report was presented regarding the Apollo scrub-turnaround capability. This turnaround plan req approximately three (3) days for a scrub which occurred after launch vehicle cryogenic loading. Approximately a year ago we estimated the turnaround could be accomplished within 44 hours (2 days).

2. During the presentation it was pointed out that we had not fully assessed the requirements to perform a second scrub-turnaround having been preceded by a first scrub-turnaround.

3. General Phillips requested that the second scrub-turnaround be assessed and that he be advised of the results. Furthermore, he requested KSC to assess the first scrub-turnaround and identify what redesign would be required to be able to achieve a 44 hour (2 day) turnaround.

4. Launch Operations has assessed the second scrub-turnaround activity and find that it can be accomplished within the same time frame as a first provided a waiver requiring a bladder bleed of the S-IVB APS can be obtained. Should a waiver not be acceptable, an additional 3½ hours of serial time would be required for the turnaround. The primary difference in the second turnaround operation will be a LM cabin reentry. This operation does not add serial time to the overall recycle operation. The attached planning chart (Minimum turnaround time to launch from scrub occurring at T-8.9 seconds) sequences the primary activities which must occur to ready the vehicle for a second and third launch attempt. The operations relative to the LM cabin entry are boxed and applicable on the second turnaround only. Assumptions similar to those presented to the board in March are also listed on the chart.

5. The operation is applicable to both LC-39 Pads A and B with the exception of the MSS move times which will be approximately two (2) hours more each way between the Park Site and Pad B. This factor, however, does not affect the overall operation since time is available after the scrub and before launch to permit the extra travel time.

C. An analysis of the scrub-turnaround plan as well as countdown operations in general indicates that response time from the initial launch attempt to a second attempt can be reduced if the following conditions would exist:

a. Move CSM and LM cryo servicing capability to the Mobile Launcher or extend the useable lifetimes. A reply on lifetime extension from MSC is awaited.

b. Simplification of cryo servicing system. Investigation of this approach is currently under way with MSC.

c. A capability to service CM and LM cryogenics in parallel assuming the safety considerations are acceptable.

d. Reduce or eliminate entry into the launch vehicle to preclude disconnect/reconnect of Dispersion System B and A blocks and the resultant serial work effort involving the LUT platforms.

e. Improved access to the SLA/IU area and a reduction in the tasks to be performed in this congested area.

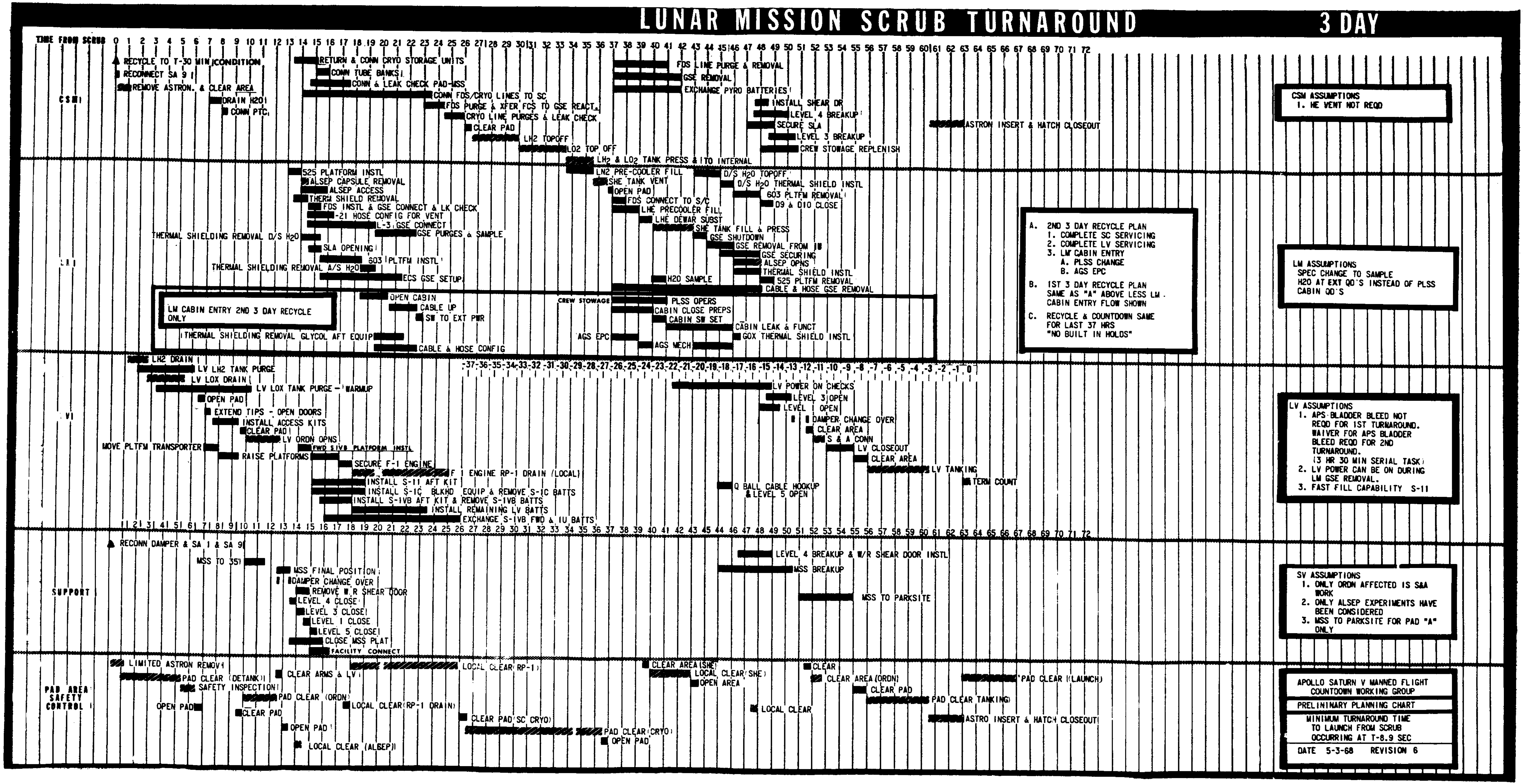
7. Engineering analysis and possible redesign could be most productively applied to the above conditions. An MSFC/KSC study of tasks requiring necessary entry into the launch vehicle is in progress with a status expected late in May. More detailed planning information in this area may be available then. Additional studies are under way between MSC and KSC on lifetime of SHe and fuel cell consumables. Results of this effort should be conclusive within the next thirty (30) days.

8. KSC will continue to optimize the scrub-turnaround as new hardware and operational experience is available. The Lunar Site Selection Board will be kept informed through its KSC member of any change in plans which alter the operational response time presented at the March 1968 board meeting. An identification of space vehicle and CSM design changes which would permit a two (2) day turnaround continues and will be addressed after assessment by MSC, KSC and MSFC.

ORIGINAL SIGNED BY
R. E. MOSER
Robert E. Moser

Enclosure: As stated

Distribution:
Thru:
Director of Launch Operations, LO
To:
Apollo Program Manager, AP


LUNAR MISSION SCRUB TURNAROUND
3 DAY
TIME FROM SCRUB
CSM
LM
LV
SUPPORT
PAD AREA SAFETY CONTROL
RECYCLE TO T-30 MIN CONDITION
RECONNECT SA 9
REMOVE ASTRON. & CLEAR AREA
DRAIN H2O
CONN PTC
RETURN & CONN CRYO STORAGE UNITS
CONN TUBE BANKS
CONN & LEAK CHECK PAD-MSS
CONN FDS/CRYO LINES TO SC
FDS PURGE & XFER FCS TO GSE REACT.
CRYO LINE PURGES & LEAK CHECK
CLEAR PAD
LH2 TOPOFF
LO2 TOP OFF
FDS LINE PURGE & REMOVAL
GSE REMOVAL
EXCHANGE PYRO BATTERIES
INSTALL SHEAR DR
LEVEL 4 BREAKUP
SECURE SLA
LEVEL 3 BREAKUP
CREW STOWAGE REPLENISH
ASTRON INSERT & HATCH CLOSEOUT
CSM ASSUMPTIONS
1. HE VENT NOT REQD
525 PLATFORM INSTL
ALSEP CAPSULE REMOVAL
ALSEP ACCESS
THERM SHIELD REMOVAL
FDS INSTL & GSE CONNECT & LK CHECK
-21 HOSE CONFIG FOR VENT
L-3 GSE CONNECT
GSE PURGES & SAMPLE
THERMAL SHIELDING REMOVAL D/S H2O
SLA OPENING
603 PLTFM INSTL
THERMAL SHIELDING REMOVAL A/S H2O
ECS GSE SETUP
OPEN CABIN
CABLE UP
SW TO EXT PWR
LM CABIN ENTRY 2ND 3 DAY RECYCLE ONLY
THERMAL SHIELDING REMOVAL GLYCOL AFT EQUIP
CABLE & HOSE CONFIG
CREW STOWAGE
AGS EPC
LH2 & LO2 TANK PRESS & ITO INTERNAL
LN2 PRE-COOLER FILL
SHE TANK VENT
OPEN PAD
FDS CONNECT TO S/C
LHE PRECOOLER FILL
LHE DEWAR SUBST
SHE TANK FILL & PRESS
GSE SHUTDOWN
GSE REMOVAL FROM
GSE SECURING
ALSEP OPNS
THERMAL SHIELD INSTL
525 PLTFM REMOVAL
CABLE & HOSE GSE REMOVAL
H2O SAMPLE
PLSS OPERS
CABIN CLOSE PREPS
CABIN SW SET
CABIN LEAK & FUNCT
GOX THERMAL SHIELD INSTL
AGS MECH
D/S H2O TOPOFF
D/S H2O THERMAL SHIELD INSTL
603 PLTFM REMOVAL
D9 & D10 CLOSE
A. 2ND 3 DAY RECYCLE PLAN
1. COMPLETE SC SERVICING
2. COMPLETE LV SERVICING
3. LM CABIN ENTRY
A. PLSS CHANGE
B. AGS EPC
B. 1ST 3 DAY RECYCLE PLAN SAME AS "A" ABOVE LESS LM CABIN ENTRY FLOW SHOWN
C. RECYCLE & COUNTDOWN SAME FOR LAST 37 HRS "NO BUILT IN HOLDS"
LM ASSUMPTIONS
SPEC CHANGE TO SAMPLE H2O AT EXT QD'S INSTEAD OF PLSS CABIN QD'S
LH2 DRAIN
LV LH2 TANK PURGE
LV LOX DRAIN
LV LOX TANK PURGE - WARMUP
OPEN PAD
EXTEND TIPS - OPEN DOORS
INSTALL ACCESS KITS
CLEAR PAD
LV ORDN OPNS
FWD S-IVB PLATFORM INSTL
MOVE PLTFM TRANSPORTER
RAISE PLATFORMS
SECURE F-1 ENGINE
F-1 ENGINE RP-1 DRAIN (LOCAL)
INSTALL S-II AFT KIT
INSTALL S-IC BLKHD EQUIP & REMOVE S-IC BATTS
INSTALL S-IVB AFT KIT & REMOVE S-IVB BATTS
INSTALL REMAINING LV BATTS
EXCHANGE S-IVB FWD & IU BATTS
LV POWER ON CHECKS
LEVEL 3 OPEN
LEVEL 1 OPEN
DAMPER CHANGE OVER
CLEAR AREA
S & A CONN
LV CLOSEOUT
CLEAR AREA
LV TANKING
TERM COUNT
Q BALL CABLE HOOKUP & LEVEL 5 OPEN
LV ASSUMPTIONS
1. APS BLADDER BLEED NOT REQD FOR 1ST TURNAROUND. WAIVER FOR APS BLADDER BLEED REQD FOR 2ND TURNAROUND. (3 HR 30 MIN SERIAL TASK)
2. LV POWER CAN BE ON DURING LM GSE REMOVAL.
3. FAST FILL CAPABILITY S-II
RECONN DAMPER & SA 1 & SA 9
MSS TO 35
MSS FINAL POSITION
DAMPER CHANGE OVER
REMOVE W/R SHEAR DOOR
LEVEL 4 CLOSE
LEVEL 3 CLOSE
LEVEL 1 CLOSE
LEVEL 5 CLOSE
CLOSE MSS PLAT
FACILITY CONNECT
LEVEL 4 BREAKUP & W/R SHEAR DOOR INSTL
MSS BREAKUP
MSS TO PARKSITE
SV ASSUMPTIONS
1. ONLY ORDN AFFECTED IS S&A WORK
2. ONLY ALSEP EXPERIMENTS HAVE BEEN CONSIDERED
3. MSS TO PARKSITE FOR PAD "A" ONLY
LIMITED ASTRON REMOV
PAD CLEAR (DETANK)
SAFETY INSPECTION
OPEN PAD
CLEAR ARMS & LV
PAD CLEAR (ORDN)
CLEAR PAD
LOCAL CLEAR (RP-1 DRAIN)
OPEN PAD
LOCAL CLEAR (ALSEP)
LOCAL CLEAR RP-1
CLEAR PAD SC CRYO
PAD CLEAR CRYO
OPEN PAD
CLEAR AREA (SHE)
LOCAL CLEAR (SHE)
OPEN AREA
LOCAL CLEAR
CLEAR
CLEAR AREA (ORDN)
CLEAR PAD
PAD CLEAR TANKING
PAD CLEAR (LAUNCH)
ASTRO INSERT & HATCH CLOSEOUT
APOLLO SATURN V MANNED FLIGHT COUNTDOWN WORKING GROUP
PRELIMINARY PLANNING CHART
MINIMUM TURNAROUND TIME TO LAUNCH FROM SCRUB OCCURRING AT T-8.9 SEC
DATE 5-3-68 REVISION 6

APPENDIX II

MSS RETURN/REMOVAL TO SUPPORT A 44-HOUR SCRUB TURNAROUND

The Mobile Service Structure (MSS) significantly influences KSC's ability to accomplish a lunar-mission scrub turnaround within 44 hours. This is attributable to two factors: (1) Establishing access to the spacecraft with the MSS servicing platforms (levels 3 and 4) which are requisite for LM and SM cryogenics re-servicing operations, and (2) These same platforms must also be "broken-up" before the MSS can be transferred to its park-site at the completion of SC cryogenic servicing. In order to allow adequate time for SC cryogenic servicing operations, the following two assumptions regarding the aforementioned factors must be made in formulating the 44-hour turnaround plan, shown in Figure 1.

a. The MSS can be returned to the launch pad, servicing platforms 3 and 4 closed, and SC access made available within 11 hours following the decision to scrub.

b. All scrub-turnaround activities subsequent to completion of the SC cryogenic servicing operations, including MSS platform breakup, can be accomplished in 12 1/2 hours.

Unfortunately, both assumptions are not currently feasible based on previously accepted MSS timelines. Reference 2 examined the MSS operations in detail and provides some insight in possibly achieving the above assumptions. Briefly, the study recommended returning the MSS to the pad prior to LV S&A operations. Basically, this mode of operation allows MSS movement and emplacement at the launch pad to occur during LV cryogenic unload and access kit installation, respectively; MSS platform 3 would then be closed and accessible by scrub plus 9 hours, cleared for S&A operations between scrub plus 10 1/2 and scrub plus 11 hours, and again available for access at scrub plus 11 hours. This would not only satisfy assumption (a), but would probably allow elimination of some additional serial time. The concept is currently being considered by KSC.

The second assumption (b) concerning MSS breakup, MSS transfer, and launch countdown all within 12 1/2 hours remains unfeasible based on presently approved modus operandi. To allow adequate time for LV S&A connection, LV cryogenic loading, and flight crew ingress/closeout activities (under the 12 1/2 hour assumption), the MSS would be required to commence its horizontal movement away from the launch pad by T-11 hours. This would then leave only 1 1/2 hours to perform platform breakup (levels 3 and 4), damper disconnect, and MSS jacking. These operations currently require three hours of serial work, all of which cannot commence until SC cryogenic GSE removal has been sufficiently completed to assure support personnel that their platform breakup activities will not be hindered.

POSSIBLE DEVELOPMENTS

KSC is currently considering two changes which could eliminate partially or totally the 1 1/2 hour deficiency discussed in the prior paragraph. The first change is concerned with a modification to the MSS servicing platforms. Currently, platforms 3 and 4 (also 1 and 2) are comprised of sliding annulus segments which ride on the top of the main platform structure and extend approximately 2 to 5 feet (varies from platform to platform). The annuli are manually extended/retracted and contain flip-up extensions at their periphery. The proposed modification would eliminate the annulus rings by extending the rigid platform structure out toward the SV and implement extendable (6-8 inches) flip-up segments at its periphery. Based on recent analysis of SV profiles and the clearance required during MSS emplacement/jacking, the extendable slip-up segments would provide the necessary clearances. The modification of platform 3 has already been approved (category III) and funded as a pilot effort, but has not yet been scheduled.

The second change proposal is concerned with the mode of operation presently employed for connection of the S&A devices. It has been suggested by LVO that consideration be given to connecting the S&A devices prior to completion of MSS breakup. Although maximum benefit from this approach would be realized only if personnel on the MSS were allowed to continue breakup functions concurrently, significant benefit would also be available regardless of the clearance requirements. An operational position calling for concurrent MSS breakup/SV closeout has been presented to KSC Safety and tentatively agreed upon.

A combination of the platform modification, modified S&A modus operandi, and/or some additional serial time savings (mentioned previously) during MSS return would most likely insure satisfaction of assumption (b).

APPENDIX III

(LM SHe Servicing)

I. INTRODUCTION

A major consideration for accomplishing a lunar mission 44 hour scrub turnaround is the re-servicing of the LM supercritical helium (SHe) system. Due to its present limited storage life capability and mission requirements, servicing of this system is a mission requirement during scrub turnaround operations (see Reference 3). This appendix reviews the servicing Ground Support Equipment (GSE), the servicing operations, and some of the considerations for accomplishing this task within the allotted time in a 44 hour turnaround.

II. GROUND SUPPORT EQUIPMENT (GSE)

There are four major units of GSE required to fill and pressurize the SHe tank:

°LHe Storage and Transfer Dewar

°Fluid Distribution Subassembly (FDS)

°Remote Control Subassembly (RCS).

°Conditioning Unit Subassembly (CUS)

A block diagram and a schematic of these items and their interfaces are shown in Figures 2 and 3, respectively.

The LHe Dewar provides liquid helium to initially fill the spacecraft tank and the CUS. It has a capacity of 670 liters of LHe. This unit is portable and is located on the level 3 platform of the MSS.

The FDS controls the flow of LHe or GHe into and out of the tank. It consists of valve assemblies, lines, temperature and pressure sensors, purge and pressurization controls, and a liquid sensor tank. The entire system is positioned in the IU above the S-IVB dome.

The RCS is also a portable unit electrically connected to the other SHe GSE units for controlling valves, pressure regulators and flow control components from distances of up to 1000 feet. Visual readouts are provided for valve positions, liquid levels and test parameters. The unit is located in the pad base area. ACE-S/C interfaces with the unit for remote loading and "top-off" operations.

The CUS is a system of cryogenic liquid vessels, heat exchangers, control equipment and instrumentation used to refrigerate incoming ambient facility GHe to near LHe temperatures. This equipment, in conjunction with the SHe Dewar, the FDS, and the RCS pre-cools, fills and tops-off the SHe tank by remote control. It is located (fixed) on the level 3 platform of the MSS.

III. SHe SYSTEM SERVICING

SHe system re-servicing during a scrub turnaround operation is accomplished in two phases:

1. Vent

2. Fill and Top-off.

Both phases are shown in either Figure 1 or the figure attached to Appendix I. The first phase is required due to pressure buildup in the tank following the previous mission servicing accomplished during countdown. After gaining access to the SLA area, a venting hose (referred to as -21) is connected to the storage vessel at a test port and the on-board helium is vented to ambient atmosphere (see Figures 1, 2 and 3). During this phase, the servicing GSE is connected, a leak check performed, and sampling and purging operations are completed. The LN_2 and LHe precoolers in the CUS are also filled during this phase.

The SHe vessel fill phase begins with transfer of LHe from the Storage and Transfer Dewar at approximately 10 psig through a vacuum jacketed transfer hose. During this process, the SHe vessel vent line is open to ambient surroundings until a liquid overflow indication is obtained at the RCS.

After liquid fill, the vent valve is closed and the tank is charged with cold (10°R) GHe to a pre-determined fill pressure corresponding to the required helium load for the mission. The SHe vessel is pressurized to 80-100 psia producing a fill density of about 8.25 lb/ft^3. This is referred to as "top-off" in Figure 1. The charge gas is facility GHe which is temperature conditioned to the required 9-10°R by passing it through the CUS.

The "top-off" operation adds mass and energy to the SHe system. The final state point of pressure/temperature is a function of the liquid fill state, fill fraction before top-off, vent pressure during LHe fill, charge gas enthalpy, and the final tank pressure after top-off. If the delivery temperature of the charge gas during top-off is higher than the 9-10°R requirement, then the final fill density will not be high enough to meet LM mission requirements. Therefore, the top-off procedure is extremely important since, if end conditions are not met, the process must be repeated with a considerable loss of serial time.

After top-off, the GSE is disconnected and removed.

IV. SHe SYSTEM TURNAROUND CONSIDERATIONS

The primary considerations or time constraints arising from SHe servicing are associated with access to the IU/SLA area, GSE set-up, and parallel operations. The tasks performed in re-servicing are as follows:

- °Install S-IVB access kits and SLA platforms (XA-525)
- °LM thermal shield removal
- °ALSEP RTG removal
- °Install -21 venting hose
- °GSE connections, leak checks, purging, sampling
- °Vent SHe storage vessel
- °CUS servicing (LN_2/LHe)
- °Dewar substitution
- °SHe vessel fill and top-off
- °GSE removal
- °Install ALSEP RTG
- °Platform removal and IU/SLA closeout

Preliminary plans indicate these operations can be accomplished in a time frame consistent with meeting the required 44 hour scrub turnaround. It must be emphasized that the time lines for each of these tasks are soft since experience at LC-39 has not been attained. There are still questions concerning paralleling of certain tasks where space for the required man-loading may be a problem. The entire timeline will require precise planning and co-ordination of tasks. Support operations involving the storage of equipment, LUT operations and MSS related tasks are extremely critical. A scrub turnaround simulation following a CDDT early in the program would be very desirable if schedule and other considerations could be satisfied.

V. OTHER CONSIDERATIONS

The present 44 hour scrub turnaround planning shown in Figure 1 is based on parallel SHe servicing with CSM cryogenic (LH_2/LO_2) servicing. This will require safety office concurrence which is doubtful due to the danger of LH_2/LO_2 spillage and the explosive hazards associated with LH_2 onto the LM servicing area. If this method of operation is not acceptable, a 44 hour turnaround cannot be accomplished under present conditions. There are two possible alternatives:

1. SHe servicing from the LUT
2. SHe storage life capability which would delete the servicing requirement.

The problems associated with item 1 have already been examined by MSC (Reference 4). These are basically:

- °Feasibility of LHe transfer over longer distances
- °Two additional CUS units required for LUT activation at over $1,000,000 apiece. Also, the CUS units are not designed for the launch vibration and flame impingement environment.
- °Lead time to activate the LUT system of about one year.

If the time required to reservice the LM SHe system is to be reduced by remote operation from the LUT, connections for servicing would have to be installed at the SLA/GSE interface. This would imply flight hardware modifications with a resultant weight penalty, design and test program, etc. As noted earlier, the time line for servicing operations consists primarily of IU/SLA access and GSE set-up. Thus, the above requirements would have to be met if this time line is to be reduced. This does not appear to be an attractive alternative.

Item 2 has been discussed in Reference 4 relating to SHe capability and mission requirements. This solution is a possibility if mission requirements are not increased and the SHe system is uprated. As shown in Figure 1, however, unless the CSM cryogenic servicing requirement is deleted or the time line is significantly reduced for this operation, there is no advantage (time related) to holding the SHe system and not re-servicing.

APPENDIX IV

SERVICE MODULE CRYO SERVICING

a. The Requirement for SM Cryo Replenishment: Preliminary Planning for the Lunar Mission Countdown indicates that LH_2 and LOX pressurization in the SM tanks for the first window of a launch opportunity will be completed by about T-28 hours. From this point onward, heat leak into the supercritical cryogens in space or on the ground will produce somewhere between .4 and 1.0 pound/hr. of water. While there are alternatives to operating the fuel cells to produce water, they are not acceptable solutions. One alternative would be to allow pressure to build up in the vessels. However, this would produce unsafe stress levels and open relief valves which may not close again. Venting the cryogens overboard would of course also deplete the quantity available for the mission.*

In terms of the cryogens, the withdrawal rate necessary to hold constant pressures under the influence of heat leak must be about .176 lb oxygen per hour per tank; for hydrogen, it must be about .026 lb per hour per tank. There are two tanks of each reactant in the lunar mission SM. To be conservative as well as to accommodate some error in the charts from which the data has been drawn, let us double the assumed heat leak rates to arrive at average loss rates for the spacecraft during ground operations as follows: 0.70 lb/hr oxygen and 0.10 lb/hr hydgrogen.

Specified minimum usable quantities of cryogens at initial loading of the SM will be 640 lb oxygen and 56 lb hydrogen.

At the end of the first launch window, then, it is expected that a minimum of 617.6 lbs of oxygen and 52.8 lbs of hydrogen should be available. At the end of a second 4-hour window occurring 48 hours later (without cryo replenishment), 584 lbs of oxygen and 48 lbs of hydrogen should still

*This topic is covered more thoroughly in Reference 5.

be available for the mission. These figures do not allow specifically for the additional amounts used when the spacecraft goes on full internal power; but since this would occur late in the countdown, the error introduced is negligible.

At the end of a design reference mission of $\approx$200 hours, a spacecraft launched after a 48 hour delay with unreplenished cryogens would still have about 200 lbs of its oxygen and 18 lbs of its hydrogen left at SM separation.

At the end of a 235-hour mission, possibly the longest that need be planned for by assuming lengthy delays in trajectory and in the lunar vicinity,* the spacecraft would still have remaining about 125 lbs of its usable oxygen and 10 lbs of its usable hydrogen.**

The conditions obtaining after various lengths of recycle or after two recycles are summarized in Table I.

However, there is an additional requirement for minimum CSM cryogenics on-board at launch. This arises from the single point failure criterion. If one of the two LOX or LH_2 tanks were to be lost at the furthest point in the mission, the other must still contain enough to enable crew survival through the abort sequence or normal completion of the mission. For return from a point in the mission where the LM is on the moon and an astronaut in the midst of an exploratory trip, a quantity approaching 200 pounds of oxygen is needed. This figure includes a rough summary of the power and metabolic requirements, cabin leak, water system purge, waste management and plumbing losses. Furthermore, for all mission planning a 10% margin on consumables is generally required. The resulting figure is the excess above normal mission requirements that must be on-board at liftoff. Alternate abort modes could of course alter this figure. In the case of LH_2, a tank loss at the same point might well result in a lower power level, during an extended trans-earth phase. The margins are similarly close.

This quick look analysis then would seem to rule out a two day recycle without replenishment of the SM cryogens. The following sections assume that replenishment of both LH_2 and LOX IS required.

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*Design Reference Mission II A MSC Report No. DM3/M-171/66 30 Oct. 1966.

**(per MPAD 3446 S (IU) 4-5-68 - curves adjusted for conditions described above).

TABLE I

Ordinary Operations	LO_2	LH_2
Initial Spacecraft Load (Spec. Mimimum Usable)	640.0#	56.0#
Boiloff Rate During all Ground Operations (see text)	0.7#/hr	0.1#/hr.
Boiloff During the First Countdown (28 hrs.) and Window (4 hours)	22.4#	3.2#
Remaining at the End of the Initial Launch Window	617.6#	52.8#
Recycle Following a Late Scrub		
Remaining at the End of a 48-hour Recycle	584.0#	48.0#
Remaining at the End of a 72-hour Recycle	567.0#	45.6#
Remaining at the end of Two 48 hour Recycle and (96 hrs.)	550.4#	43.2
Remaining at the End of One 48-hour Recycle and One 72-hour Recycle (120 hrs.)	533.6#	40.8#
Mission Needs		
Required for a Design Reference Mission (200 hrs.)*	384#	33.#
Required for a 235-hour Mission at Nominal Use Rates*	459#	38.#

*No tolerances are given in the source data.

b. Operations, constraints and sequencing to reservice LH_2 and LO_2 during a scrub-turnaround

Reservicing SM cryogenics requires that the MSS be brought back into position on the launch pad and the separate LO_2 and LH_2 Storage Units, S14-065 and S14-066, be installed on the pad and connected to the respective Transfer Units, S14-032 and S14-026, on the MSS-22 foot level. Tube banks must also be reconnected in this interval. These operations can be accomplished concurrently with MSS emplacement and preparation and with connection operations at the spacecraft.

Somewhere in the scrub operation, it will be necessary to dump accumulated fuel cell water, a manual operation which can be handled by astronauts or ground crew members inside the CM. This operation is not particularly time critical, but it will probably be required again before liftoff since, for such relatively short recycle sequences as 48 or 72 hours, the fuel cells would not be shut down.*

Figure 4 represents a plan that has been studied by SCO for re-servicing fuel cell cryogenic in a minimum time. One reservation, the first bar in the figure "connect scuppers and cryo and gas lines to S/C" has not been demonstrated capable of being done in eight hours. SCO appears to have confidence in the realism of the rest of the indicated times, however. The close of the sequence permits platform #4 to be withdrawn and the MSS to be removed from the launch pad, as indicated elapsed time of 22 1/2 hours.

---

*Cooling requires about 26 hours; warm up and conditioning require about four hours; the fuel cells would have to be on line by about T-17 hours. Most of this time must be deducted from contract life.

Contract life of a fuel cell, which may be a consideration if more than one recycle is required, is presently 400 hours. Expected requirements for a first window launch would be:

Altitude chamber test	48 hours
Nominal countdown plus window	~40
Maximum mission (assumed)	235
	323 hours

Contract also requires twelve starts @ 25 hours/start--Six of these starts can be added to the 400 hours to make 550 hours--contractually. Pratt & Whitney has operated one of these cells for as long as 1800 hours.

c. Concurrent Operations

The major operation which may be required to be conducted concurrently with cryogenics re-servicing is the supercritical helium re-servicing of the LM descent stage. That operation is conducted mainly from MSS platform #3 just below platform #4. Constraints between these operations are primarily a matter of safety.

d. Safety Considerations

Somehow, the safety hazards and near impossibility of performing work around large vehicle tanks filled with boiling, ultracold cryogenic propellants is obvious enough. Draining LV cryogenics prior to the MSS return is an initial requirement following a scrub which may involve personnel doing any significant amount of work on the space vehicle. Re-servicing the LV cryogenics after other operations have been completed must similarly await MSS removal -- 850 feet of separation is generally taken as the point where LOX loading can begin.

During a scrub turnaround operation of only a few days duration, hypergolics and helium spheres need not be re-serviced except possibly for a need to bleed accumulated bubbles in the S-IVB/APS systems (see Appendix V). This means that personnel working nearby are exposed to relatively large quantities of these hazardous fluids, some pressurized above 50% design burst.

Static conditions of this nature are currently considered acceptable for specifically approved limited access by KSC Safety. It should be kept in mind, nevertheless, that rupture of any of these vessels, small or large, will most likely result in a chain reaction that would greatly endanger all personnel within the pad perimeter.

During SM cryogenic servicing, only personnel directly involved in the specific operation are normally permitted in the pad area. Discrete hazards intervals shown in Figure 4 include LH_2 Top-off, LO_2 Top-Off and pressurization. A different crew is used for LH_2 top-off than is used for LO_2 top-off. Pressurization must be done remotely so that personnel are not exposed as pressures in the supercritical vessels rise above 25% design burst. A five-minute stabilization period is required when the vessels have reached operating pressures (automatically switching the already operating fuel cells from externally supplied reactants to internal stores). Personnel may then return to complete the cryo bridge breakup so that the MSS platform can be retracted.

Performing LH_2 and LO_2 top-off concurrently would not only hazard two crews at once but would increase the overall hazard because of the proximity of servicing ports for the two reactants.

A hazard of some degree from spilled cryogens at the SM levels would also exist for personnel working in the SLA area if such exposure were not already prohibited by the general explosive hazards associated with these fluids. It is clear that any appreciable reduction in total turnaround time during cryogenics top-off will involve a compromise with the concern for safety.

e. Potential Shortcuts and Related Costs

Remote control of cryogen top-off flow from outside the pad area would allow a savings of the hour for changing servicing crews.

Servicing LH_2 and LO_2 concurrently by one crew-- or two--would save up to three and a half hours if other personnel were evacuated concurrently with the FDS purge, etc., operation immediately preceding.

As mentioned above, the last two of these possibilities involve some compromise with safety. Hydrogen vapor in particular has achieved a reputation for its propensity to turn rapidly into a high energy ball of rather colorless flame.

A final alternative, which would greatly enhance the capability to recycle within 44 hours, involves extensive redesign in the SM and GSE to permit remote cryogen servicing from the ML. Figure 5 shows the relative position of the SM fuel cells/cryo tanks and SA #8. It can be seen that redesign for remote servicing would consist of either some device to reach completely around the SM or the installation of internal SM plumbing from the tanks to the swing arm area. Either of these approaches can be ruled out on the basis of cost, lead time for implementation and the significant increase in inert weight of the Service Module they would likely entail. It is also questionable whether the servicing equipment could stand the long lines necessary to cross the umbilical arm and whether there is space on the ML to locate the units.

APPENDIX V

APS BLADDER BLEED

The oxidizer and fuel containers of the S-IVB/APS are bladder tanks, the same as those used for the LM/RCS oxidizer. The bladders have been noted to develop bubbles inside following propellant loading. These bubbles are presently regarded as having two sources. The first is associated with the release of gases retained in solution under ullage conditions at the servicer. The second is associated with a slight but significant and demonstrated permeability of the bladder to the exchange of pressurant (helium) and propellant vapor. The pressurant is viewed as entering directly into solution after passing through the bladder until an equilibrium is reached. The mechanism by which dissolved gases come out of solution to form a "sensible" bubble is associated with pressure-temperature fluctuations. At high pressures, the concentration of gases in the propellant can be higher. A drop in pressure would result in this gas coming out of solution.

In light of this situation, MSFC has established a policy for bladder bleed operations in the launch area. These are summarized as follows:

1. Following hypergolic loading, all engines of the APS are test fired. Prior to this firing, the oxidizer bladders are to be bled until no more bubbles are in evidence.

2. Since there are a number of temperature cycles under low ullage pressure conditions (50 psi) between the test firing and launch, an additional bladder bleed on both propellants (4 tanks) is to be conducted at about T-32 hours in the countdown. The operation takes about 1-1/2 hours.

3. At T-35 minutes in the countdown, the helium isolation valve is opened and operating pressure is applied to the ullage side of the propellant tanks. If the launch is scrubbed before this event and APS environmental control is maintained during recycle operations, no bubble venting is required for launch within five days of the last

bubble vent operation. However, if operating pressure is applied and the system is vented back to a holding pressure, a bubble bleed <u>is</u> required. On the other hand, if the operating pressure is maintained through the recycle, the five-day rule applies.

A delay in launch of 48 or 72 hours beyond the initial window would not push the allowable hold-without-bleed time of five days. Holding the APS system at operating pressure is permissible even though personnel access to the vicinity may be required, once the pressure has stabilized and if there is no evidence of leakage. Environmental control must be maintained without the turnaround sequence.

Helium pressurization in the final hour of countdown is controlled remotely and accomplished from ML 6000 psi supplies. It brings the APS helium tanks to 3200 psi. Since this is in excess of 50% design burst (about 5252), the condition is classed as a major hazard. KSC Safety standards do not rigidly exclude access after these conditions have stabilized but they do severely limit it. These vessels can be vented back to a 1500 psi holding pressure without effecting pressures in the propellant tanks. This venting operation (by remote control) would take about 30 minutes.

Launch delays greater than four days (or two successive scrubs adding up to this much time) requires the bubble venting operation to be reperformed.*

<u>Operations and Sequence Constraints</u>

The APS bladder bleed operation is a manual operation. The GSE involved is a hand-cart transported assembly, one each for oxidizer and fuel. The carts are normally stored on MSS platform #2. The operation itself requires about 6 persons on platform #2; others must evacuate the area. Preparations and later breakup of the GSE are not constraining on other operations being conducted, but the actual bleed operation requires the local area to be cleared of uninvolved personnel so that about three hours of serial time must be devoted to it.

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*A previous requirement to purge the helium of the bladder to remove propellant vapors has not been deleted. Vapor mixing upstream of the helium check valves is now excluded as a significant concern.

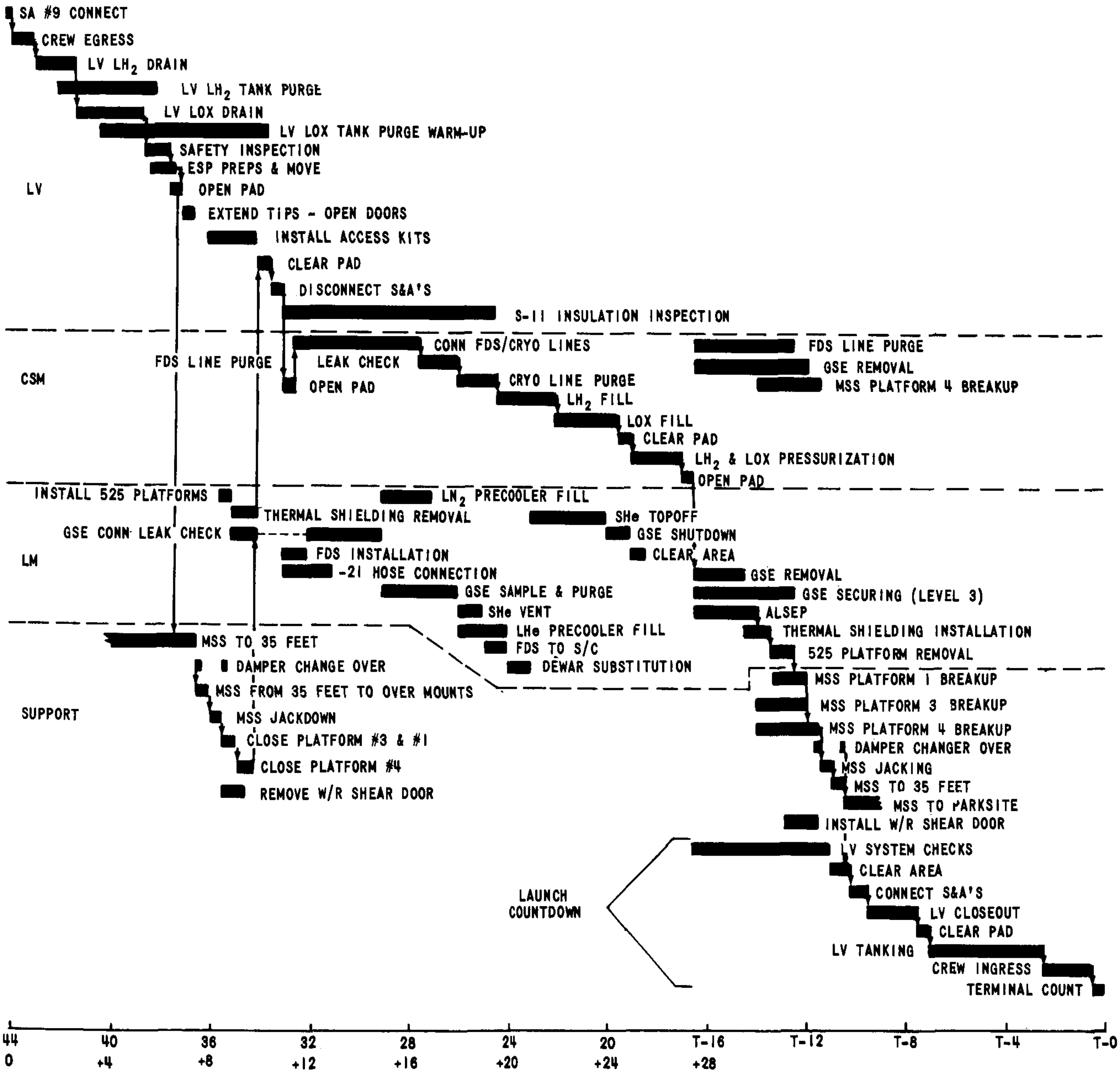

FIGURE 1 - CONJECTURAL 44-HOUR SCRUB TURNAROUND FLOW WITH HAZARDOUS SC OPERATIONS

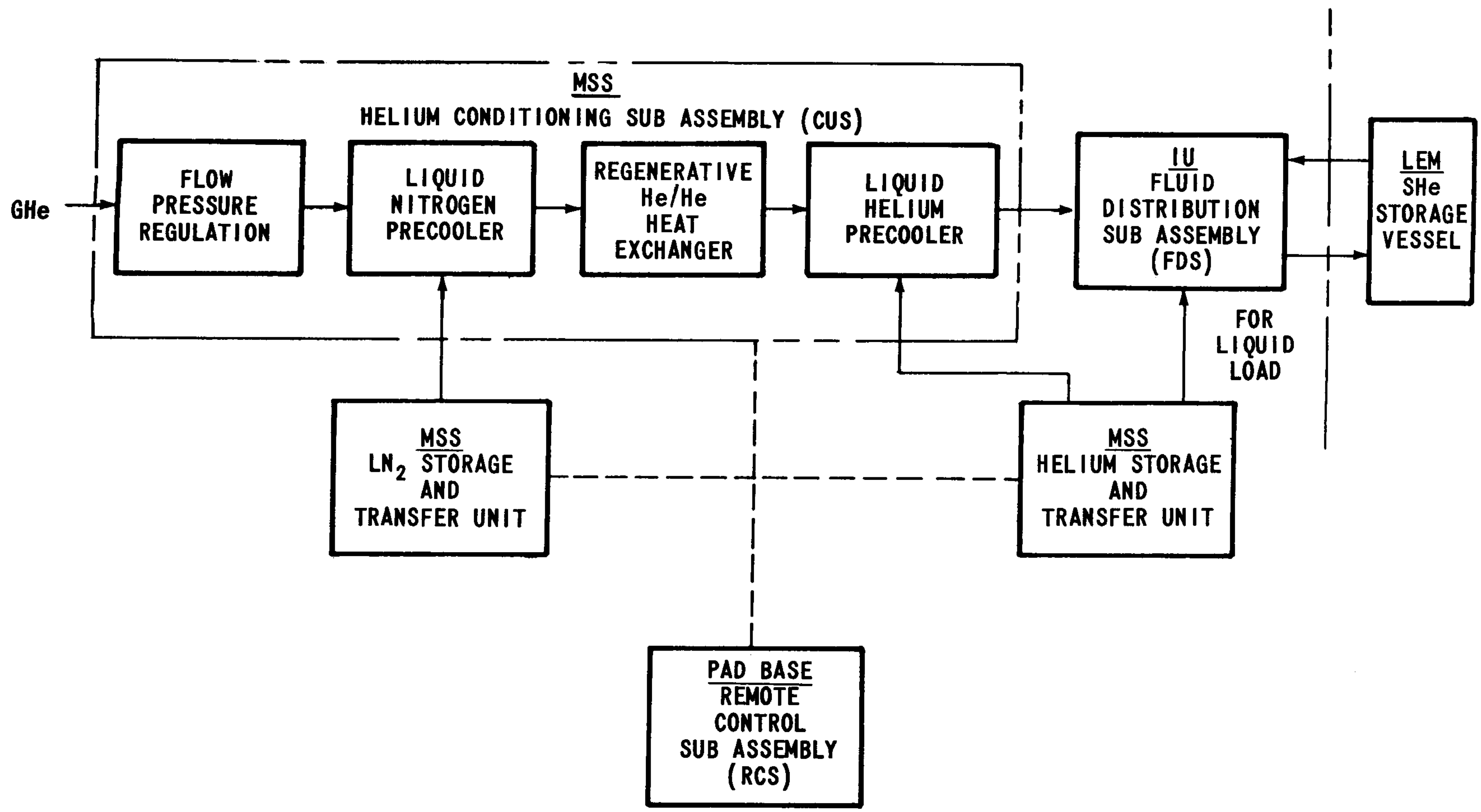

FIGURE 2 - BLOCK DIAGRAM - SUPERCRITICAL HELIUM SERVICING EQUIPMENT

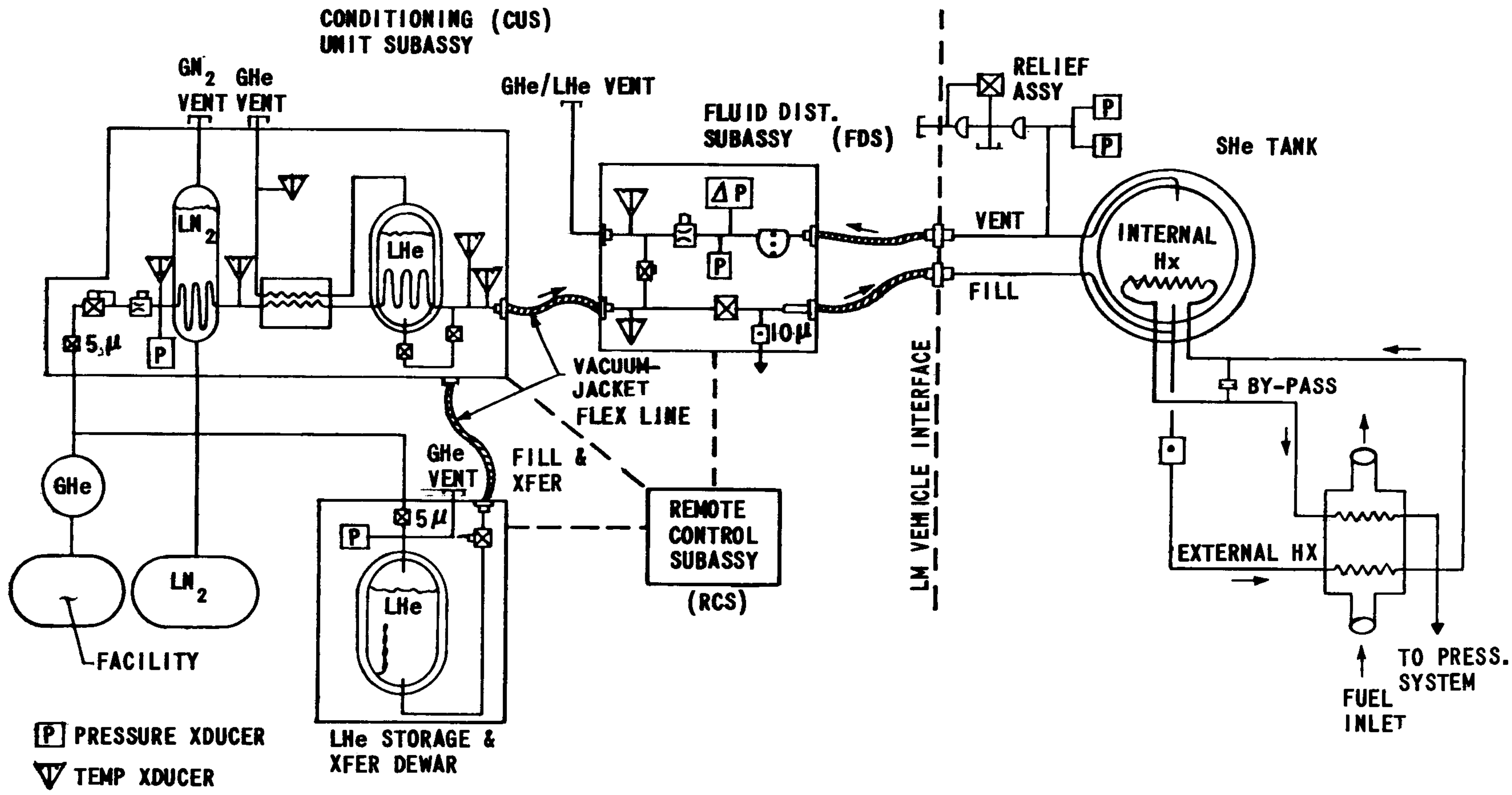

FIGURE 3 - GSE/SHe TANK INTERFACES

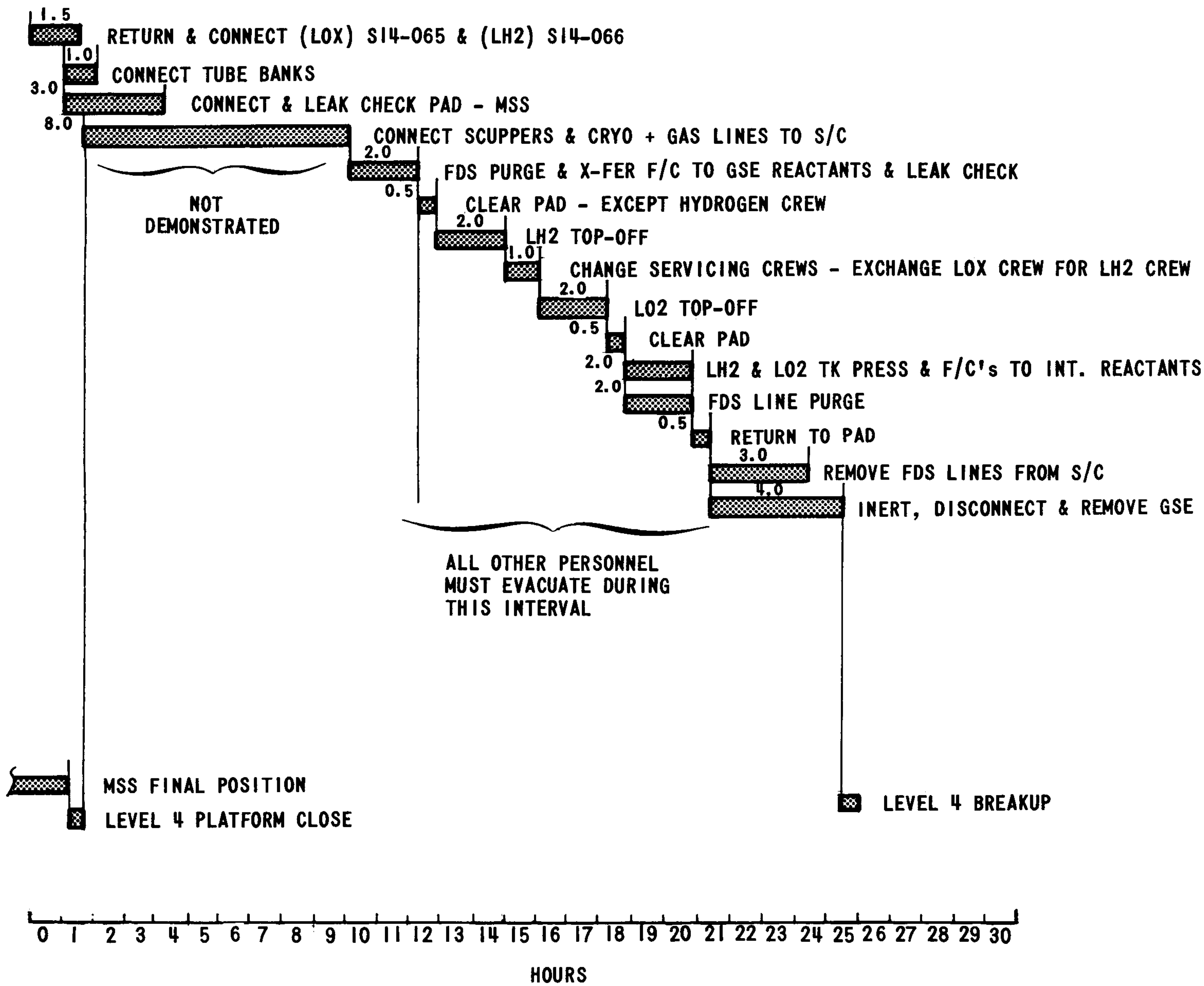

FIGURE 4 - SM CRYOGENICS SERVICING

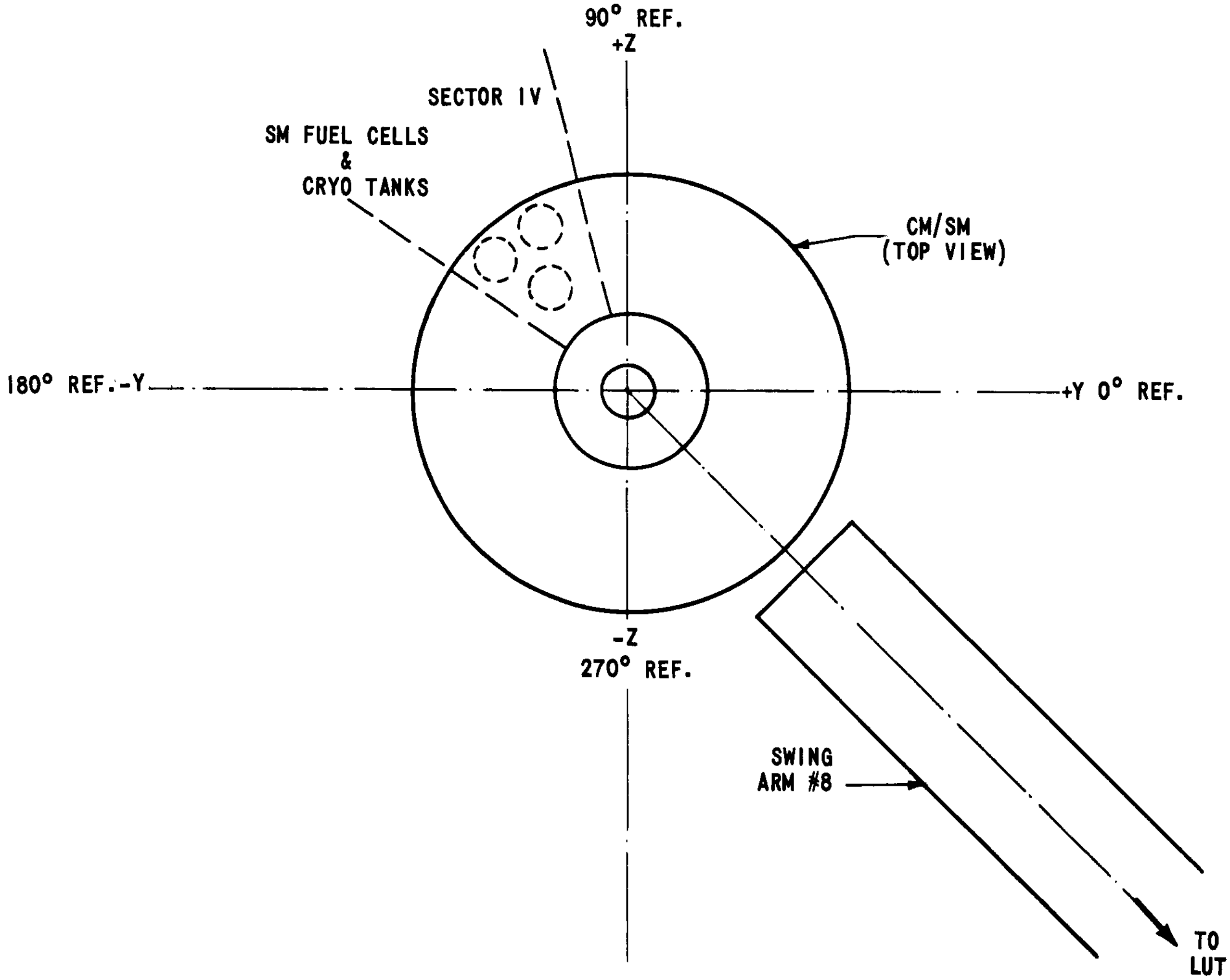

FIGURE 5 - VIEW OF CM/SM FROM ABOVE SHOWING RELATIVE POSITION OF THE SM FUEL CELLS AND CRYO TANKS IN RELATION TO SA #8

BELLCOMM, INC.

SUBJECT: Operational Constraints and Requirements Associated with a 44-Hour Turnaround Capability for the Apollo/Saturn V - Case 320

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